NASA Cold Land Processes Experiment (CLPX): Atmospheric Analyses Data Sets

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ABSTRACT

This paper describes the Local Analysis and Prediction System (LAPS) and Rapid Update Cycle (RUC20) atmospheric analyses data sets available as part of the Cold Land Processes Field Experiment (CLPX) data archive. The LAPS data set contains spatially- and temporally-continuous atmospheric and surface variables over Colorado, Wyoming, and parts of the surrounding states. The analysis used a 10-km horizontal grid with 21 vertical levels and hourly temporal resolution. The LAPS archive includes 46, 1-dimensional surface fields, and 9, 3-dimensional upper-air fields, spanning the period 1 September 2001 through 31 August 2003. The RUC20 data set includes hourly, 3-dimensional atmospheric analyses over the contiguous United States and parts of southern Canada and northern Mexico, on a 20-km horizontal grid, with 50 vertical levels. The RUC20 archive contains 46, 1-dimensional surface fields, and 14, 3-dimensional upper-air fields, spanning the period 1 October 2002 through 31 September 2003. The data sets are archived at the National Snow and Ice Data Center (NSIDC) in Boulder, Colorado at nsidc.org/data/clpx/data.html.

1. Introduction

For many applications, Earth-system scientists can benefit from continuous (in space and time) representations of state variables (such as air temperature, precipitation, and snow depth). Unfortunately, most field observations are both spatially and temporally irregular. In the atmospheric sciences, a data assimilation procedure is commonly used to produce a continuous (in x, y, z, and t) and physically consistent representation of the atmosphere from a collection of irregular observations. The data assimilation procedure applies filters to extract the signal from the generally noisy observations, performs interpolation in space and time, and uses atmospheric models to construct state variables that were not sampled by the observational network and to ensure the analyzed data are physically consistent. The models are based on general fluid mechanics equations applied to Earth's atmosphere. These equations are the conservation laws applied to individual air parcels: conservation of momentum (equations of motion), conservation of energy (first law of thermodynamics), and conservation of mass for dry air and moisture (continuity equations). The resulting analysis is an optimal combination of the available observations and the model representation. Thus, the analysis data set contains the advantage of spatial and temporal continuity, but also includes the possible disadvantage of being removed from the original observations. In what follows, we summarize the atmospheric analysis-related data available within the Cold Land Processes Field Experiment (CLPX; Cline et al. 2005) archive. The data sets are archived at the National Snow and Ice Data Center (NSIDC) in Boulder, Colorado at nsidc.org/data/clpx/data.html.

2. Atmospheric analysis models and data descriptions

a. Local Analysis and Prediction System (LAPS) analyses

The Local Analysis and Prediction System (LAPS) (McGinley et al. 1991; Albers 1995; Albers et al. 1996; Birkenheuer 1999; Hiemstra et al. 2005), developed and operated by the NOAA's

Forecast Systems Laboratory (FSL), combines numerous observed meteorological data sets into a unified atmospheric analysis typically with a time interval of an hour or less. An analysis contains both spatially- and temporally-continuous atmospheric state variables in addition to special atmospheric and land-based fields over Colorado, Wyoming, and parts of the surrounding states (Fig. 1). The quasi-operational analysis used for development at FSL uses a 10-km horizontal grid (125 x 105) with 21 isobaric vertical levels and hourly temporal resolution. The purpose of a system such as LAPS is not only to provide an up-to-date atmospheric state representation for nowcasting and assessment, but it can also serve as a mechanism to initialize local-scale mesoscale weather forecast models.

LAPS makes use of a wide range of observational data sets as part of its analyses including: 1) surface observations from regional surface networks every 5 minutes to 3 hours, 2) hourly surface aviation observations, 3) Doppler radar volume scans every 6-10 minutes, 4) wind and temperature Radio Acoustic Sounding System (RASS) profiles from the NOAA Demonstration Profiler Network every 6-60 minutes, 5) satellite visible data every 15-30 minutes, 6) multi-spectral image and sounding radiance data every 60 minutes, 7) Global Positioning System (GPS) total precipitable water vapor determined from signal delay, and 8) automated aircraft observations.

LAPS, like many analysis systems, begins with a first guess or background field interpolated to a finer grid from coarser large-scale forecast model output. The source for LAPS background fields are generally RUC forecasts (described below), but it is also configured to use ETA, MRF, and NOGAPS forecasts (high resolution backgrounds from MM5 or WRF can also be used for a 4D-variational application if lateral boundary conditions are not critical). The LAPS analysis is a series of routines that then takes the local observations with other nationally disseminated data, and modifies the background field to match those observations. In addition, quality control measures are used to assess the observations and reject those that are deemed unsuitable. Different analysis methods are currently used in the set of analysis routines consisting of Kalman, traditional Barnes, and variational minimization techniques, depending on the data set (e.g., Daley 1991).

A recent and valuable addition to the LAPS system is termed the “hot start” method for model initialization. Conventional numerical weather models take a few hours to “spin up” convective activity – precipitation processes that are vital to weather forecasting. The hot start method developed at FSL utilizes the cloud field that is analyzed from satellite, radar, surface, and aircraft data and imposes a balanced vertical motion field in regions of the “observed” analyzed clouds with constraints based on stability and cloud type. Because this balanced field is dynamically consistent, when the 3-dimensional winds and temperatures are inserted into a forecast model, the model accepts them directly and, thus, precipitation spin-up time is either greatly reduced or in most cases completely eliminated.

The CLPX LAPS analyses archive spans the period 1 September 2001 through 31 August 2003 (roughly the 2002-2003 water years) at an hourly time increment. It includes the three-dimensional and surface variables listed in Table 1, and covers the entire LAPS Regional Operational Cooperative domain (Fig. 1). For reference, Fig. 1 also outlines the CLPX Meso-scale Study Areas (MSAs). Hiemstra et al. (2005) has compared the LAPS analyses outputs (air temperature, relative humidity, wind speed, and precipitation) with CLPX meteorological station observations (Goodbody et al. 2005). Figure 2 provides an example LAPS archive application:

the data set was used to define a “blizzard index” (defined to be the product of the storm-total snow accumulation and wind speeds greater than 5 m s^{-1}) for the CLPX North Park MSA.

b. Rapid Update Cycle (RUC20) analyses

NOAA's FSL also operates a 20-km version of the Rapid Update Cycle (RUC20) atmospheric analysis and forecast system (Benjamin et al. 1998, 2002). The system produces high-frequency (every 1h) 3-dimensional objective atmospheric analyses over the contiguous United States and parts of southern Canada and northern Mexico, on a 20-km horizontal grid, with 50 vertical levels. The system assimilates the following observations: commercial aircraft (relayed through ACARS - Aircraft Communications, Addressing, and Reporting System); NOAA 405 MHz wind profilers; 915 MHz boundary-layer profilers; rawinsondes and special dropwinsondes; surface/METAR - land (V, p_{sfc}, T, T_d) reporting stations and buoys; RASS (Radio Acoustic Sounding System) virtual temperatures; VAD (velocity-azimuth display) winds from NWS WSR-88D radars; GOES total precipitable water estimates; GOES cloud-top pressure; GOES high-density visible and IR cloud drift winds; SSM/I total precipitable water estimates; and GPS total precipitable water.

The CLPX RUC20 analyses archive spans the period 1 October 2002 through 31 September 2003 at an hourly time increment. The archive includes the three-dimensional and surface variables listed in Table 2. Like the LAPS data, the RUC20 data are available for a wide range of applications, including studies of large-scale weather patterns and timing, and surface energy- and moisture-flux analyses.

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Table 1. Summary of LAPS variables available within the CLPX data archive.

1-D Surface Fields:	
U Surface Wind Component (m s^{-1})	Ground Temperature (K)
V Surface Wind Component (m s^{-1})	60 Minute Snow Accumulation (m)
1500m Pressure (Pa)	Storm-Total Snow Accumulation (m)
Surface Temperature (K)	60 Minute Liquid Precipitation Accum (m)
Surface Dew Point Temperature (K)	Storm-Total Liquid Precipitation Accum (m)
Vertical Velocity (m s^{-1})	Integrated Total Precipitable Water Vapor (m)
Relative Humidity (%)	Cloud Base (m)
MSL Pressure (Pa)	Cloud Top (m)
Temp Advection (K s^{-1})	Cloud Ceiling (m)
Potential Temperature (K)	Cloud Cover (0-1)
Equivalent Potential Temperature (K)	Cloud Analysis Implied Snow Cover (0-1)
Surface Pressure (Pa)	Clear Sky Water Temperature (K)
Vorticity (s^{-1})	IR Channel 4 (11.2u) b-temp: averaged (K)
Mixing Ratio (g kg^{-1})	IR Channel 2 (3.9u) b-temp: averaged (K)
Moisture Convergence (g kg^{-1} s^{-1})	LAPS Derived Albedo (0-1)
Divergence (s^{-1})	Soil Moisture, 3 Levels (m m^{-1})
Potential Temperature Advection (kg s^{-1})	Cumulative Infiltration Volume (m)
Moisture Advection (g kg^{-1} s^{-1})	Depth To Wetting Front (m)
Surface Wind Speed (m s^{-1})	Wet/Dry Grid Point (-)
Colorado Severe Storm Index (-)	Evaporation Data (m s^{-1})
Surface Visibility (m)	Snow Cover (0-1)
Fire Danger (-)	Snow Melt (m^3 m^{-3})
Heat Index (-)	Wetting Front Soil Moist Content (m^3 m^{-3})
3-D Upper-Air Fields:	
Geopotential Height (m)	U Wind Component (m s^{-1})
Temperature (K)	V Wind Component (m s^{-1})
Specific Humidity (kg kg^{-1})	Wind Omega (Pa s^{-1})
Relative Humidity (%)	Fractional Cloud Cover (0-1)
Relative Humidity with respect to liquid (%)	

Table 2: Summary of RUC20 variables available within the CLPX data archive.

1-D Surface Fields:	
MAPS Mean Sea Level Pressure (Pa)	Soil Vol. Moist. at 40 cm Below Surf. (wfv)
Soil Temperature at Surface (K)	Soil Vol. Moist. at 160 cm Below Surf. (wfv)
Sensible Heat Flux (W m-2)	Soil Vol. Moist. at 300 cm Below Surf. (wfv)
Latent Heat Flux (W m-2)	Soil Type (0..9 (Zobler))
Net Longwave Radiation at Surface (W m-2)	Vegetation Type (SiB Model) (0..13, as in SiB)
Precipitation Rate (kg m-2 s-1)	Icing Potential SIGMET/AIRMET (-)
Resolvable (large) Scale Precipitation (kg m-2)	Lightning (-)
Sub-grid (convective) Scale Precip (kg m-2)	Rate of Water Dropping Canopy to Ground (-)
Precipitable Water (kg m-2)	Net Short Wave Radiation at Surface (W m^{-2})
Pressure at Tropopause (Pa)	Snow Accumulation (m depth, 100 kg m^{-2})
Potential Temperature at Tropopause (K)	Snow Depth (m)
U-component of Wind at Tropopause (m s-1)	Surface Runoff (kg m^{-2})
V-component of Wind at Tropopause (m s-1)	Sub-surface Runoff (kg m^{-2})
Convective Available Potential Energy (J kg-1)	Canopy Water (kg m^{-2})
Convective Inhibition (J kg-1)	Snow T., 5cm Below Surf. or Top Soil (K)
Soil Temperature at 5 cm Below Surface (K)	Snow T., 10cm Below Surf. or Top Soil (K)
Soil Temperature at 20 cm Below Surface (K)	Water Vapor Mixing Ratio at Surface (kg kg^{-1})
Soil Temperature at 40 cm Below Surface (K)	Snow Accumulation (m depth, 100 kg m^{-2})
Soil Temperature at 160 cm Below Surface (K)	Snow Density 5cm Below Snow Surf. (kg m^{-3})
Soil Temperature at 300 cm Below Surface (K)	Air Temperature, 2m Above Ground (K)
Soil Vol. Moist. at Surface (wfv)	Water Vapor Mix. Rat., at 2m (kg kg^{-1})
Soil Vol. Moist. at 5 cm Below Surface (wfv)	U-component of Wind, at 10m (m s^{-1})
Soil Vol. Moist. at 20 cm Below Surface (wfv)	V-component of Wind, at 10m (m s^{-1})
3-D Upper-Air Fields:	
Pressure (Pa)	Cloud Water Mixing Ratio (kg kg^{-1})
Height (gpm)	Rain Water Mixing Ratio (kg kg^{-1})
Virtual Potential Temperature (K)	Ice Mixing Ratio (kg kg^{-1})
Water Vapor Mixing Ratio (kg kg^{-1})	Snow Mixing Ratio (kg kg^{-1})
U-component of Wind (m s^{-1})	Graupel Mixing Ratio (kg kg^{-1})
V-component of Wind (m s^{-1})	Cloud Ice Number Concentration (m^{-3})
Vertical Velocity (Pa s^{-1})	Turbulence Kinetic Energy (J kg^{-1})

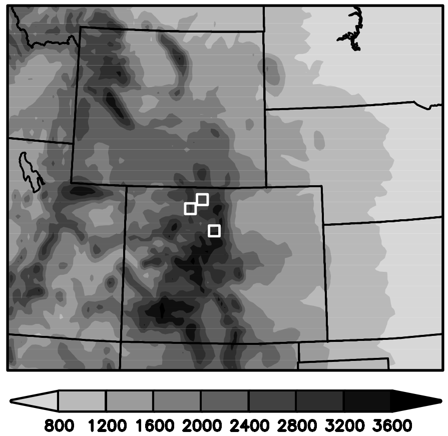

Figure 1. The LAPS analyses domain and topography (gray shades, meters). Also included are outlines of the three, 25 by 25 km, CLPX Meso-scale Study Areas (MSAs).

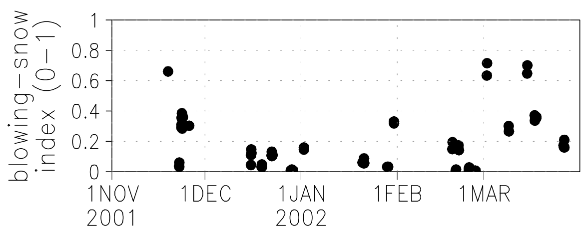

Figure 2. An example CLPX LAPS archive application: the data set was used to produce a "blowing-snow index" (defined to be the non-dimensionalized product of the storm-total snow accumulation and wind speeds greater than 5 m s^{-1}) for the CLPX North Park MSA.